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1 Purpose

This document provides the a high-level introduction to the PreSat and NanoSail-D mission systems and operations. Mission objectives are discussed and descriptions of system components are provided.

2 Scope

This document describes PreSat and NanoSail-D systems at a relatively high level, neglecting specific details of technology.

The top level descriptions will cover:

- Satellite Bus and Payload Systems
- Deployment Systems
- Launch System
- Mission Operations and Ground Systems
- Pre-Launch operations

3 Acronyms and Definitions

ADS	Attitude Determination System
AFB	Air Force Base
ARC	Ames Research Center
CCAM	Collision Avoidance Maneuver
CMOS	Complementary Metal Oxide Semiconductor
COMM	Communications (system)
COTS	Commercial Off the Shelf
DNA	Deoxyribonucleic acid
E&PO	Education and Public Outreach
EDU	Engineering Development Unit
EPS	Electrical Power Subsystem
GFP	Green Fluorescent Protein
GSE	Ground Support Equipment
I^2C	I-Squared-C Serial Data Bus.
ICD	Interface control document/drawing
IR	Infrared
KRad(Si)	Kilo-Rad (related to Silicon absorbed dose rates)

LED	Light Emitting Diode
LV	Launch Vehicle

Acronyms and Definitions Continued

MeV	Mega Electron-Volts
MLI	Multi-layer Insulation
MOC	Mission Operations Center
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MPEs	Maximum Predicted Environments
NEA	Non-explosive Alternative (deployment actuator); also, NEA Electronics Corp.
NORAD	North Atlantic Air Defense
nT	Nano-Tesla
PCR	Polymerase Chain Reaction
POC	Point of Contact
P-POD	Poly Picosatellite Orbital Deployer
Rad(Si)	Unit of Radiation Measurement (related to Silicon absorbed dose rates)
RBF	Remove Before Flight
RCS	Reaction Control System
RF	Radio Frequency
RNA	Ribonucleic acid
SBS	Society of Biomolecular Screening
SSE	Science Support Equipment
STC	Space Technology Center
T&DRS	Tracking and Data Relay System (Ground Station)
TBS	To be specified

4 References

Some of the descriptions in this documents are drawn or derived from the following references:

[1] Falcon-1 User's Guide

[2] Reserved

[3] "Spacecraft Systems Engineering", Edited by Peter Fortescue, John Stark, and Graham Swinerd; 3ed, 2003, John Wiley and Sons.

[4] Poly Pico-sat Orbital Deployer ICD, May 2004; Armen Toorian, California Polytechnic University. **(TBR)**

[5] Mission Operation Plan, (unpublished)

5 System Overview and Objectives

The PreSat nano-satellite and NanoSail-D (NSD) campaign mission system is comprised of four major functional physical segments. They are the Space Segment (Satellite and Deployer), Ground System and Flight Operations Segment, System Safety and Mission Assurance Segment, and Launch. The function of the system is to meet the objectives of the mission objective summarize in paragraph 5.1 below. This document will describe each segment of the system.

5.1 Mission Objectives

The overall goal of the the PreSat Project is to utilize autonomous, in-situ bioanalytical and sample management technologies for investigations in support of the Advanced Capabilities Division non-exploration and exploration objectives. Experiment requirements are described in Science Requirements A240-0702-XR004.

Minimum success criteria for PreSat are focused on demonstrating that the satellite can provide the necessary environment for executing the biological experiment planned for the later PharmaSat mission. Extended success for PreSat includes detection of actual biology growth during orbit.

Minimum success criterion for NanoSail-D (NSD) is to demonstrate that the ARC Nanosatellite bus and MSFC NanoSail-D payload can be integrate and delivered for launch. Extended success for NSD includes validation of the sail deployment mechanism and demonstration of de-orbit performance by use of a solar-sail device.

In addition, both the PreSat and Nanosail-D missions will demonstrate the ability to launch on the Falcon-1 vehicle and operate portable ground stations for near-equatorial orbits.

Figure 2 provides a typical mission integration schedule sequence for activities up to launch integration. The PharmaSat Mission schedule follows this sequence.

The standard launch integration process consists of the following:

Launch – 8 months or more	**Contract signing and authority to proceed** • Estimated payload mass, volume, mission, operations and interface requirements • Safety information (Safety Program Plan; Design information: battery, ordnance, propellants, and operations) • Mission analysis summary provided to the Customer within 30 days of contract
Launch – 6 months	**Final payload design, including: mass, volume, structural characteristics, mission, operations, and interface requirements** • Payload to provide test verified structural dynamic model
Launch – 4 months	**Payload readiness review for Range Safety** • Launch site operations plan • Hazard analyses
Launch – 3 months	**Verification** • Review of Payload test data verifying compatibility with Falcon 1 environments • Coupled payload and Falcon 1 loads analysis completed • Confirm payload interfaces as built are compatible with Falcon 1 • Mission safety approval
Launch – 4-6 weeks	**System Readiness Review (SRR)** • Pre-shipment review (per stage; prior to shipment to the launch site)
Launch – 2 weeks	**Payload arrival at launch location** • Flight readiness Review (FRR)
Launch – 9 days	**Payload encapsulation**
Launch – 7 days	**Payload mate to Launch vehicle**
Launch – 1 day	**Launch readiness Review**
	Launch
Launch + 4 hours	**Post-Launch Reports- Quick look**
Launch + 4 weeks	**Post-Launch Report- Final Report**

Figure 1, Generic LV Mission Integration Schedule

6 Launch Segment

The launch system for this mission is comprised of a launch vehicle, integration facilities and equipment, and launch facilities provided by Space-X at Reagan Test Site, Omelek Island in the Kwajalein Atoll. Omelek Island is part of the Kwajalein Atoll in the Marshall Islands which is located 2500 miles southwest of Hawaii. Omelek is controlled by the U.S. Army's Reagan Test Site (RTS). A generally representative overview of and the launch sequence is detailed in Figure 3. ***Details of the payload separation sequence are provided in table 1.***

Figure 2, Falcon-1 Sample Flight Profile, Two-Burn Mission

IMPORTANT: Figure 3 provides notional data only which is not specific to the planned mission. The expected mission orbit is described in section 8.3, Space Environments.

Table 1, Launch Sequence and Payload Separation Events

EVENT	Time (sec)	Elapsed Time (min:sec)
Optional Hold at T-10 min		
Liftoff	0.00	
Tower clear	4:00	00:04
MECO	157.44	02:37
Stage separation	158.44	02:38
2nd Stage ignition	162.44	02:42
Fairing separation	191.44	03:11
SECO1	556.82	09:16
Settling thruster ON	561/82	09:21
Deploy payload (primary)	566.82	09:26
Deploy payload (PreSat)	817.82	13:36
Deploy payload (NSD)	1067.82	17:46
Second stage relight	3169.82	52:48
SECO2	3186.82	53:05

6.1 Launch Vehicle

The launch vehicle for the PharmaSat mission is the four-stage Minotaur Launch Vehicle with a 61-inch diameter fairing. Figure 4 provides the main characteristics of the Minotaur launch vehicle.

The Minotaur LV will launch the USAF primary payload in addition to the PharmaSat secondary payload. Both will be accommodated in the 61-inch fairing. The Figure 5 details of the 61-inch diameter fairing envelope.

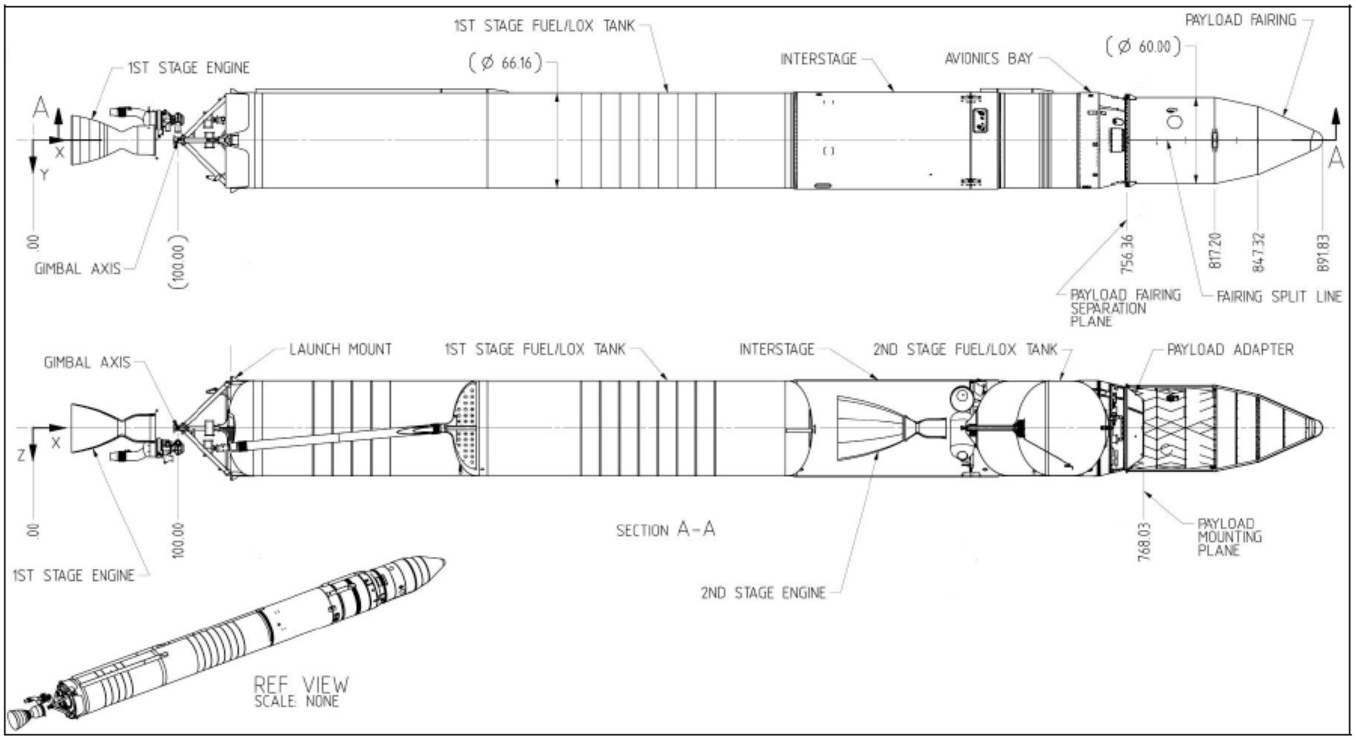


Figure 3, Falcon-1 Launch Vehicle Layout (inches)

6.1.1 Upper Stage Configuration

The Falcon 1 LV will launch a TBD primary payload in addition to the NanoSail-D and PreSat secondary payload. Both will be accommodated in the 60-inch fairing. Figure 5 provides details of the 60-inch diameter fairing envelope.

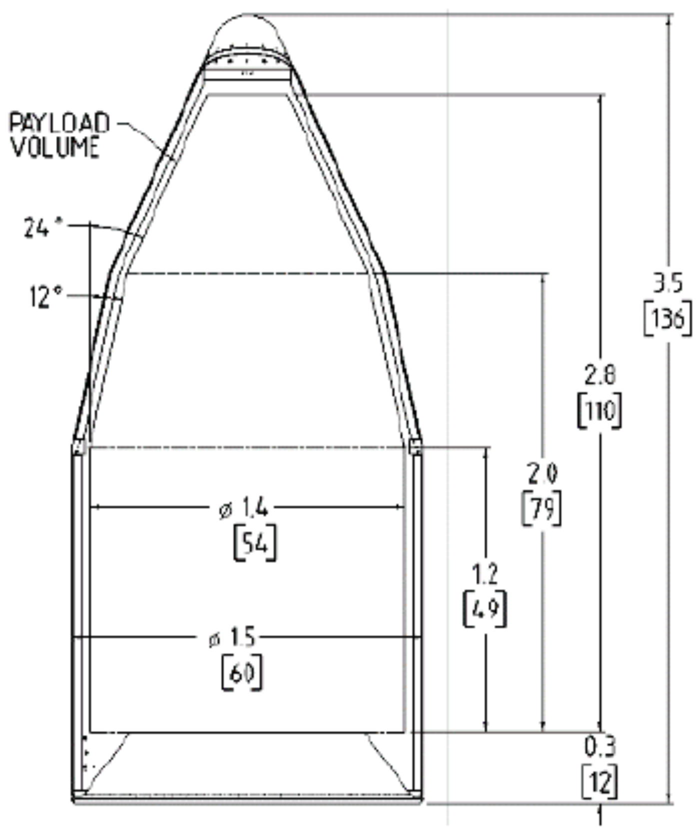


Figure 4, Falcon 1 Fairing, Dimensions in Meters [inches]

Figure 6 illustrates the launch configuration for the payloads on the rideshare adapter that will be encapsulated within the fairing.

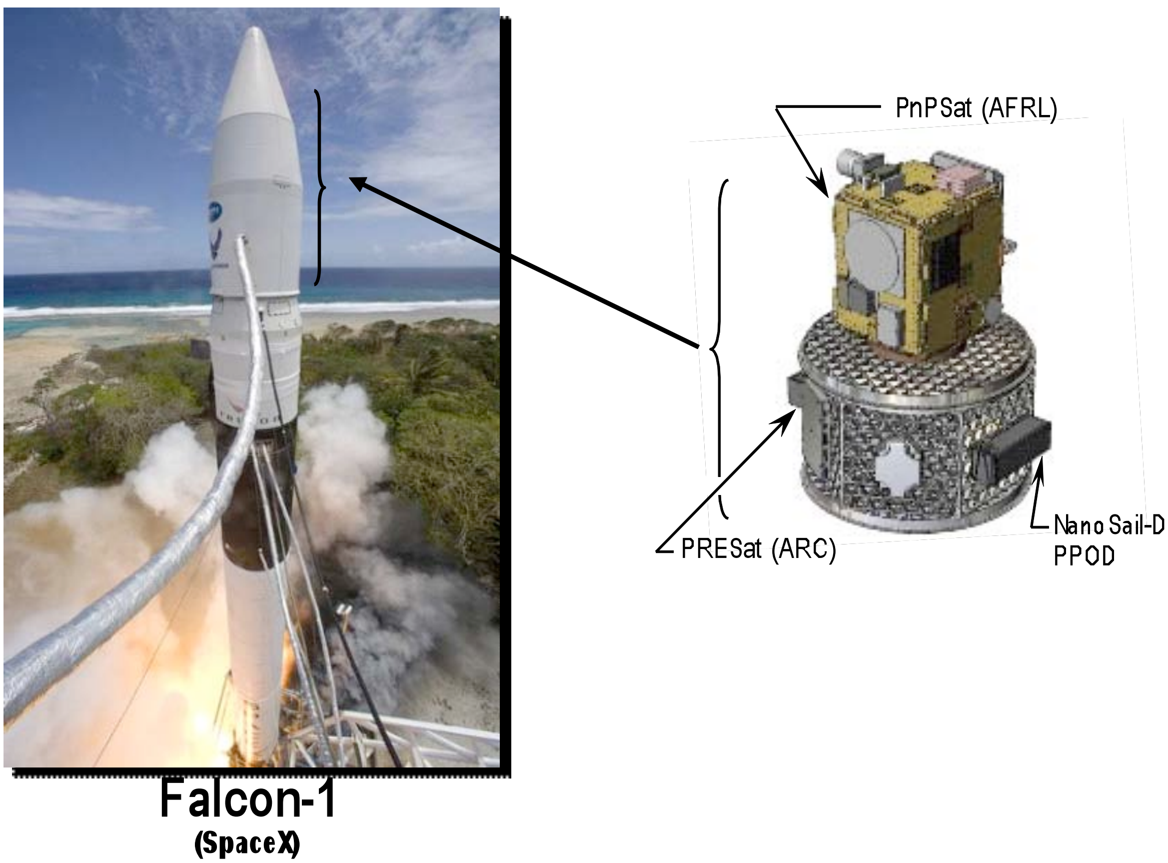


Figure 5, Launch and Deployment Arrangement

6.2 Launch Environments

Launch environments information including random vibration, shock, acoustics, quasi-static loading, and pressure information can be found in the Falcon-1 User's Guide. The vibration interface at the secondary payload interface will differ somewhat from the Falcon vibration and shock specification.

6.3 Launch Services, Facilities and Crew

Launch services, facilities, and crew are provided by the Space Exploration Technologies (Space-X).

6.4 Ground Processing, Integration, and Launch Operations

Launch operations are described in the Falcon 1 Payload User's Guide [1] as follows:

Ground and launch operations are conducted in three major phases:

a. Launch Vehicle Integration — Assembly and test of the Falcon 1 vehicle,

b. Payload Processing/Integration — Receipt and checkout of the satellite payloads, followed by integration with PPOD and verification of interfaces previously installed and tested on the RideShare Adapter (RSA).

c. Launch Operations — Includes final encapsulation of the upper stage with the payload fairing, transport and erection of the launch vehicle.

6.5 Space Environment

The space environment for the Satellite is defined by the selected orbit. The orbit for the missions is elliptical with apogee at 685 km, perigee at 340 km and inclination of approximately 9 degrees. The satellite will be in sunlight varying from approximately 58 to 72 minutes of each orbit, and eclipse time will vary from approximately 22 to 36 minutes (dependent on variation of RAAN) in each orbit such that sunlight and eclipse duration orbit add up to approximately 94.8 minutes total per orbit.

Ionizing radiation for electrons and protons trapped in the Van Allen Belts will be encountered. Approximate electron energies may range as high as 10,000 MeV. Approximate proton energies may range as high 1,000 MeV. Energies are most severe in the area of the "South Atlantic Anomaly" located in an area centered roughly at longitude 325 degrees and about 90 degrees wide and below the equator between 0 and -45 degrees [3]. In this region the Van Allen belts reach below 500 km altitude.

The natural radiation dose accumulation rate can be expected to be around 300 Rads (Si) per year. For a month the dose would then be roughly 25 Rads. This value is based on a thickness of Aluminum structure of 100 mils. PreSat and NSD use COTS electronics which may fail at a total dose radiation somewhere below 5 KRads(Si) [3]. Such total dose levels should not be possible for either satellite during their primary mission duration (approximately 2-4 weeks for PreSat, and 3 days to 2 weeks for NSD).

Single Event Latchup in CMOS and burnout in MOSFET devices may be caused by heavy ions, protons and neutrons. But for missions of this duration the probability of such an event prior to completion of the primary mission is very low.

Electrostatic charging of the spacecraft will occur which can lead to arcing. This effect is most severe if differential charging of the spacecraft surface occurs. The spacecraft are protected from this by use of grounding between structural elements.

Micrometeoroid and debris impacts are expected. The effective flux is reduced by the small size of the spacecraft and the short mission duration. The mass of impact objects is expected to be generally below 0.001 g. Average velocity of these objects is 11 km/s but ranges from zero to twice orbital velocity. Average density is 2.8g/cm3.

Space vacuum pressures may be in the range of 10-11 Pa for the specified orbit. This reduced pressure can cause outgassing vaporization of surface atoms.

Magnetic Field flux density will vary for the orbit in the approximate range from 30,000 nT to 60,000 nT.

Solar thermal radiation, Earth-emitted IR, Earth-reflected (Albedo) radiation and Moon-reflected radiation will heat the spacecraft. The amount of radiation depends on the launch date and orbit. Direct solar radiation can range from 1367 W/m2 to 1414 W/m2. Earth-emitted radiation will be approximately 218 to 244 W/m2 depending on orbit and weather. Albedo is expected to be roughly 30 percent of solar radiation.

7 System Safety and Mission Assurance Segment (SS&MA)

SS&MA is a separately managed system segment of this Mission. This is done to increase the visibility of the project safety approach and ensure it is managed in a crosscutting, integrated fashion.

SS&MA management incorporates four primary areas: Laboratory Safety, Mission and System Safety, Range Safety*, and Launch Facility Safety*. In addition, the safety of equipment and personnel are managed in fabrication shops, manufacturer's facilities, university laboratories, and in all transportation of equipment and personnel.

One special requirement of this project is to transport sealed payloads with BY4743 (*Saccharomyces cerevisiae*) yeast to the pre-launch payload processing facility Reagan Test Site.

The yeast is identified as a bio-safety level 1 (BSL-1) micro-organism posing insignificant threat to humans, and it will be sealed in the payload canister at 1 atmosphere. Regardless, special safety procedures will be implemented to limit the possibility of spills, and to ensure safe clean-up procedures can be implemented during transport and at the Wallops facility.

* Range safety and launch facility safety are managed by the launch operations organization.

8 Mission Systems

Mission systems are comprised of all mission-specific elements not provided by the launch system. Included here are ground support equipment (GSE) and science support equipment (SSE), payload preparation and integration procedures, a ground station for tracking and data relay, mission operations facilities and support personnel, ground communications systems, the spacecraft and payload, space deployment systems, on-orbit operations procedures, and space environments.

8.1 GSE & SSE

Mission-specific ground support equipment (GSE) and Science Support Equipment (SSE) will be developed for reliable handling, integration, and experiment preparation of the PharmaSat Science Payload System and Spacecraft.

8.2 Ground Systems and Mission Operations Segment

8.2.1 Operations Locations and Facilities

Pre-launch ground operations will take place as described in Table 1 below:

Table 1, Payload Processing Scenario

Process/Operation	Location
P-POD attachment to Rideshare adapter (RSA)	Space Access Technologies, Colorado
Biology Loading, PreSat Assembly, and NSD Assembly; both with “RBF” plugs installed.	NASA Ames Research Center, Moffett Field, CA
PreSat and NSD Final Functional Checkout and Preflight re-installation of “RBF” lockout to disable all power including radio power.	Reagan Test Site, Kwajalein Atol, Omelek Island.
PreSat and NSD Integration to P-POD deployers and removal of “RBF” lockout.	Reagan Test Site, Kwajalein Atol, Omelek Island.
Fairing encapsulation – hands off payloads.	Reagan Test Site, Kwajalein Atol, Omelek Island.

Other pre-launch ground operations include procedural meetings with the launch operators and the managers of the primary payload.

* Functional tests must take place outside the launch preparation facilities to prevent undesired RF interference with ordnance and launch facility systems.

8.2.2 Mission Operations

Figure 9 illustrates the ground segment architecture for mission operations.

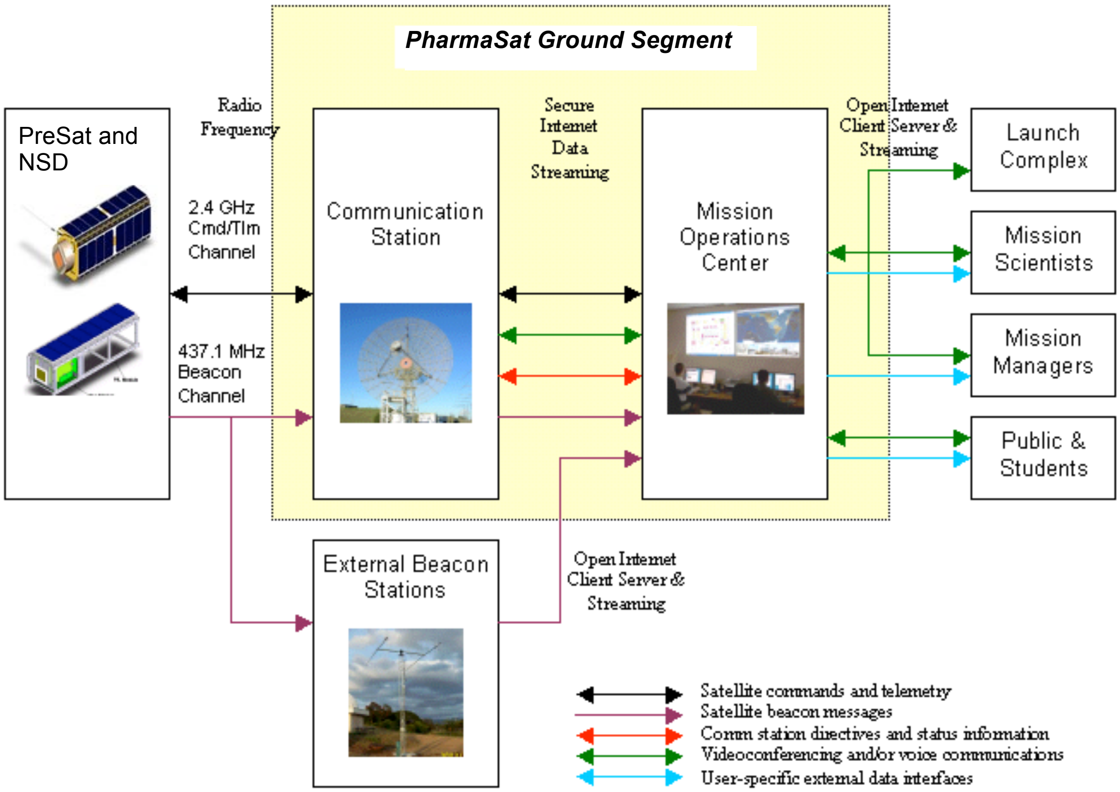


Figure 6, Mission Operations Communications Overview

Two-way radio communications for satellite commands and telemetry is supported by use of the SRI 18m parabolic dish facility. This facility connects via secure internet to control node workstations to support interactive crew activities and contact procedure execution during realtime operations. Control nodes exist at the primary MOC in Building 240 at NASA ARC, the back-up MOC in the CREST facility (Building 583c) in the NASA Research Park, at SCU's PharmaSat Lab, and within the SRI facility.

PharmaSat's UHF amateur radio beacon will be received by the SRI station as well as by external amateur radio operators. Externally received beacon data may be submitted to the PharmaSat program through the mission web site as part of the mission's EPO program as well as for collecting additional satellite data.

Figure 10 depicts the notional command and data handling architecture for the PharmaSat ground segment.

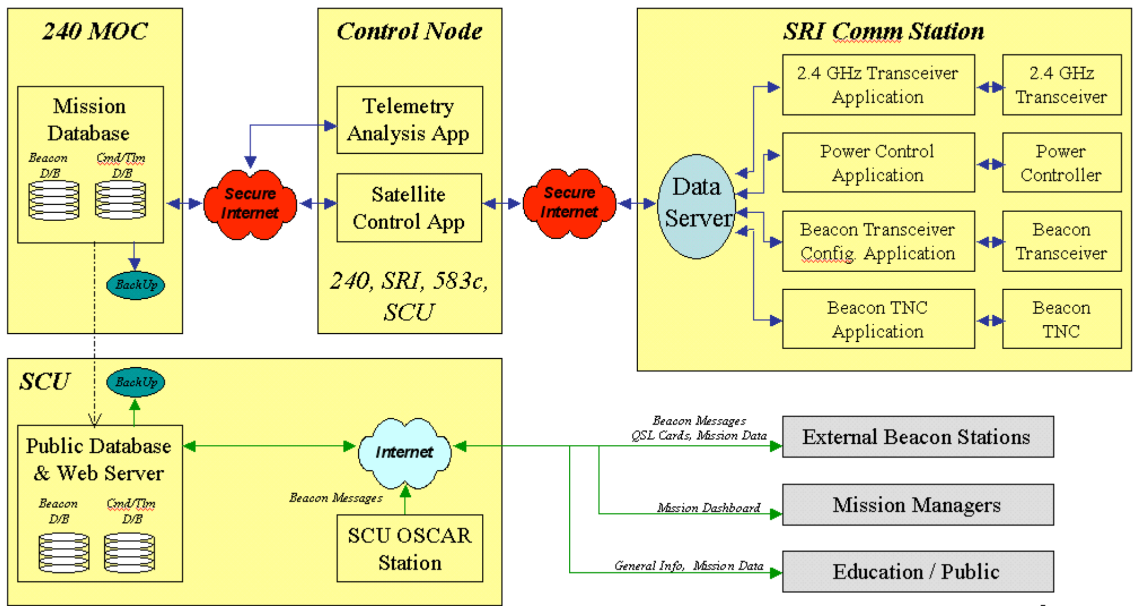


Figure 10, Ground Segment Command and Data Handling Diagram

8.2.3 Concept of Operations:

PharmaSat is secondary spacecraft payload providing a true science experiment. It is a Nano-satellite weighing approximately 5 kg and designed to perform a biological microgravity experiment using a common yeast organism (*Saccharomyces cerevisiae*). Pharmasat will operate in a nearly circular mission orbit with altitude of 460km at an inclination of approximately 40.5 degrees with initial RAAN to be specified by the Primary spacecraft customer. Nodal precession will be roughly -6 degrees per day.

The test biology strain of yeast was selected for its appropriateness to the planned experiment which measures the response of the yeast to the space environment as compared to a control experiment performed on Earth.

Mission Scenario Walk Though (Tentative Sequence):
The yeast is prepared and integrated into two identical "biomodule" payloads by the PharmaSat Project science team at Ames Research Center, Moffett Field, CA. These payloads are then attached to their respective PharmaSat spacecraft bus systems and the full PharmaSat satellite assemblies are completed. One of these satellites will be launched and the other becomes a ground control experiment.

A functional checkout is performed at ARC to verify full nominal operation of all PharmaSat systems.

PharmaSat main power is disabled, and the satellites and GSE hardware and software are hand carried to a final checkout location near the Minotaur launch facilities at Wallops Island, VA. A Hobo temperature logger accompanies each satellite.

In parallel to the above activity, one P-POD deployer is temporarily integrated to the Orion-38 upper stage of the Minotaur launch vehicle for fit and function test. This may take place either at Vandenberg AFB, CA, or at the Wallops Island Launch processing facility.

Prior to transferring to the launch processing facilities, the PharmaSat that has been selected for flight undergoes final secondary battery charging, physical inspections, and functional checkout at the offsite preparation facility in the Wallops Island area. The ground control PharmaSat will also be fully charged. From this point forward in this text, the flight PharmaSat will be referred to as PharmaSat-A, the ground control PharmaSat will be referred to as PharmaSat-B.

Both PharmaSats again have their main power disabled by insertion of a Remove-Before-Flight (RBF) plug. Then, PharmaSat-A is inserted in the P-POD which engages the Footswitch that keeps the satellite powered off until deployment. The RBF is removed and the P-POD cover is then latched by use of the “NEA” (Non-explosive Alternative) release mechanism.

Once latched inside the P-POD, there is no communication connection and PharmaSat-A is unpowered except for the operation of a real time mission clock.

PharmaSat-B remains unpowered and is prepared for return to Ames research center.

Then, PharmaSat –A is transferred to the Wallops island launch processing facilities. The P-POD is integrated with an isolator bracket and mounted on the Minotaur.

PharmaSat-A is now in the physical control of the launch operations ground crew.

The LV fairing will be encapsulated approximately 30 days prior to launch. Temperature control is maintained in the fairing until roughly four minutes prior to launch.

PharmaSat-A and the P-POD are isolated from the vibration and shock of the solid booster launch events by an energy absorbing vibration isolation assembly.

On-orbit, following shutdown of the Orion-38 (4^{th} stage) motor and release of the primary payload, PharmaSat-A will separate by actuating a trap door on the P-POD followed by extension of a pusher spring that sends PharmaSat-A out of the P-POD.

After a short time, the 4^{th} stage will execute an RCS gas (nitrogen) depletion function.

Immediately after deployment PharmaSat begins to generate power using its solar arrays. For up to 2 or 3 days PharmaSat may operate autonomously without starting the payload experiments. However, the mission manager may decide to send an experiment start command at the earliest opportunity after satellite health is sufficient to start the mission. Key indicators of satellite pre-experiment stability and health include temperature stability, battery charge state, and microgravity stability. This health stabilization period will also be used to get precise orbital tracking data from NORAD / SpaceTrack.

When the orbital track is known, the SRI ground station antenna can be programmed to follow PharmaSat each time it appears on the horizon and passes overhead. These are data transfer opportunities which last a few minutes each, and occur twice each day.

When orbital conditions are stable, a "Start Experiment" signal will be sent to the PharmaSat-A payload from the MOC. The payload will begin to increase temperature to acceptable setpoints in an internal fluid reservoir and on the biology wellplate that holds the yeast. Once temperature stability has been achieved, a complex series of events is executed to perform the Yeast experiment. For the next 96 hours data will be collected from the experiment and subsequently transmitted to the ground.

If PharmaSat-A does not get a “Start Experiment” command from the ground it will start the experiment autonomously after a predetermined number of days (presently set at 3 days from time of deployment).

PharmaSat-B will be commanded to execute its experiment at the same time as PharmaSat-A so the two can be compared for statistically significant differences in response of the biology.

When the biology experiment is completed, a decision will be made to either shut down the biomodules, or continue collecting data for engineering and E&PO purposes.

Within a few weeks, or months, and depending on operating conditions, a decision will be made to conclude the experimental and extended operations portion of the mission.

PharmaSat-A will de-orbit naturally within about 3 years after launch.

8.2.4 Ground Communications Station

Figure 11a pictures the mission’s Communication Station, owned by SRI International and located in the Palo Alto foothills. The station has been refurbished for the PharmaSat mission and supports communications both in the 2.4 GHz band (for PharmaSat’s primary command and telemetry channel) as well as in the UHF band (for PharmaSat’s beacon downlink channel).

(a) 18-Meter Diameter main Dish (b) SCU Amateur Radio Antenna

Figure 11, Satellite Ground Stations

External amateur radio stations generally use a dual-Yagi antenna system as shown in Figure 11b (this is the SCU amateur radio station which will be dedicated to receiving PharmaSat beacon messages as part of the mission's education program). Beacon messages received by amateur radio operators around the world may be submitted to the PharmaSat program through a public web site.

8.3 Spacecraft Deployment System

Figures 12 and 13 illustrate the Poly Picosatellite Orbital Deployer (P-POD) developed by California Polytechnic University. There are no pyrotechnic devices required for deployment. Once in orbit, a standard pyro-separation signal electrically releases the door latch. This releases a spring loaded end gate allowing an internal spring to push the spacecraft out and away from the deployer and the fourth stage.

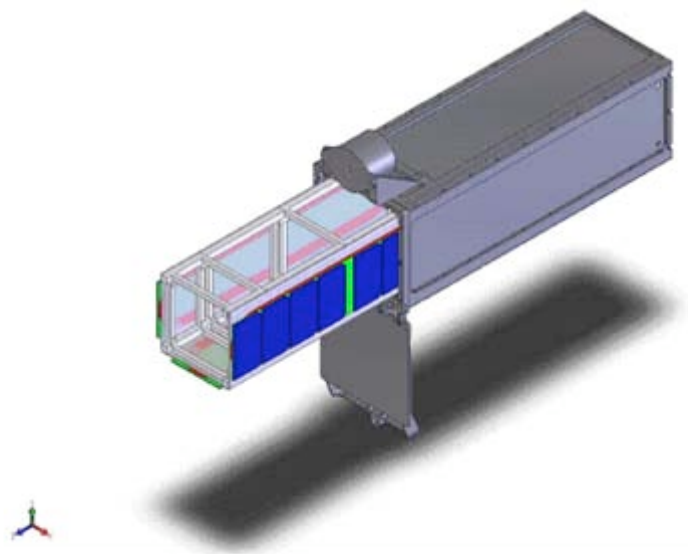


Figure 7, P-POD with Spacecraft in Hatchway

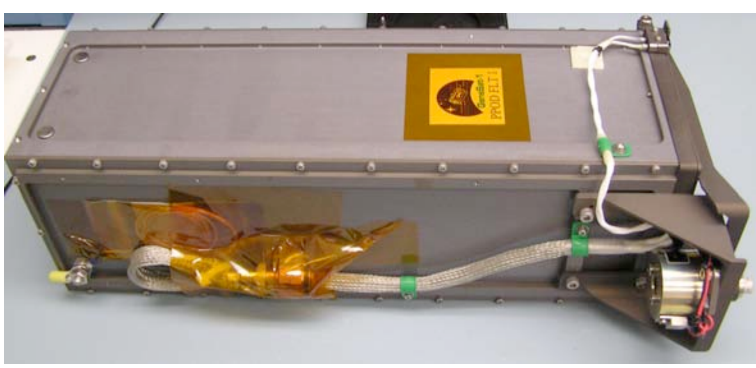


Figure 8, P-POD MKII

8.4 Satellite

Please refer to Figures 14 and 15. The PharmaSat satellite is the integrated system comprised of the satellite bus and the payload. The bus provides power all power, uplink/downlink communications, and attitude determination. The bus also manages remediation of single event effects. The payload provides accommodation for the biological experiment, associated support hardware, fluidics, electro-optics, electronics, and sensor systems. The bus and payload communicate through a serial I^2C databus.

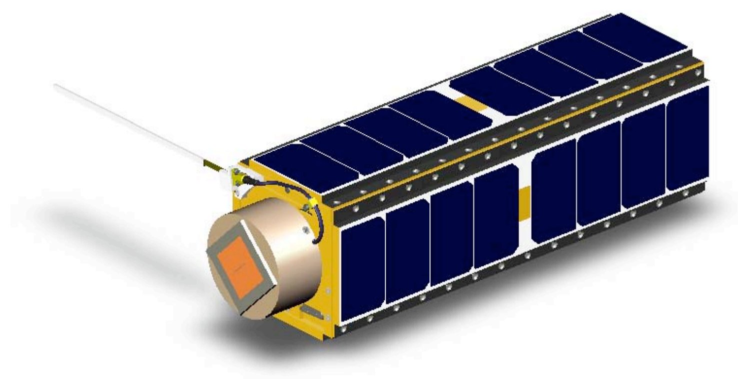


Figure 9, PharmaSat Satellite

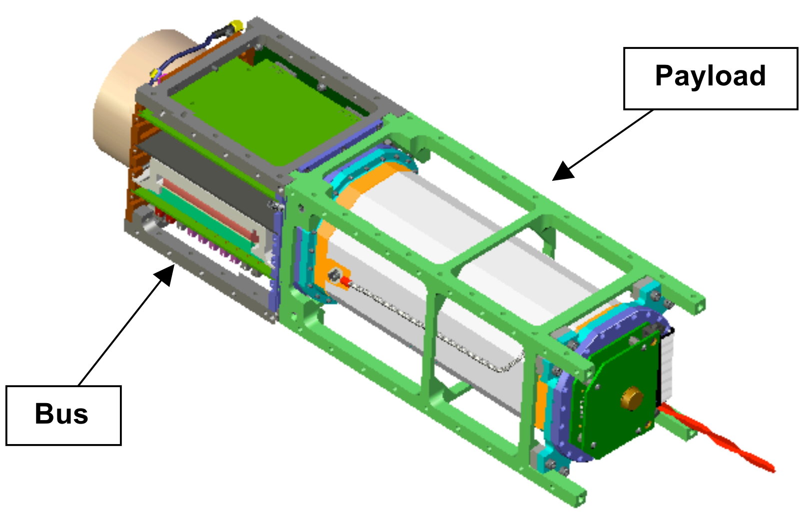


Figure 10, PharmaSat with the Solar Arrays Removed for Visibility

8.4.1 Satellite Electronic Systems

Figure 16 illustrates the major functional blocks of the PharmaSat electronic systems. The large block to the left represents the spacecraft bus with electrical power subsystem (EPS), micro-controller, attitude determination system (ADS) and communications subsystem (COMM). Memory is not represented here, but is a significant block of the bus electronics. The larger block to the right represents the payload electronics subsystem. The interconnection between the systems contains power and serial data lines. These systems are described in more detail in subsequent sections.

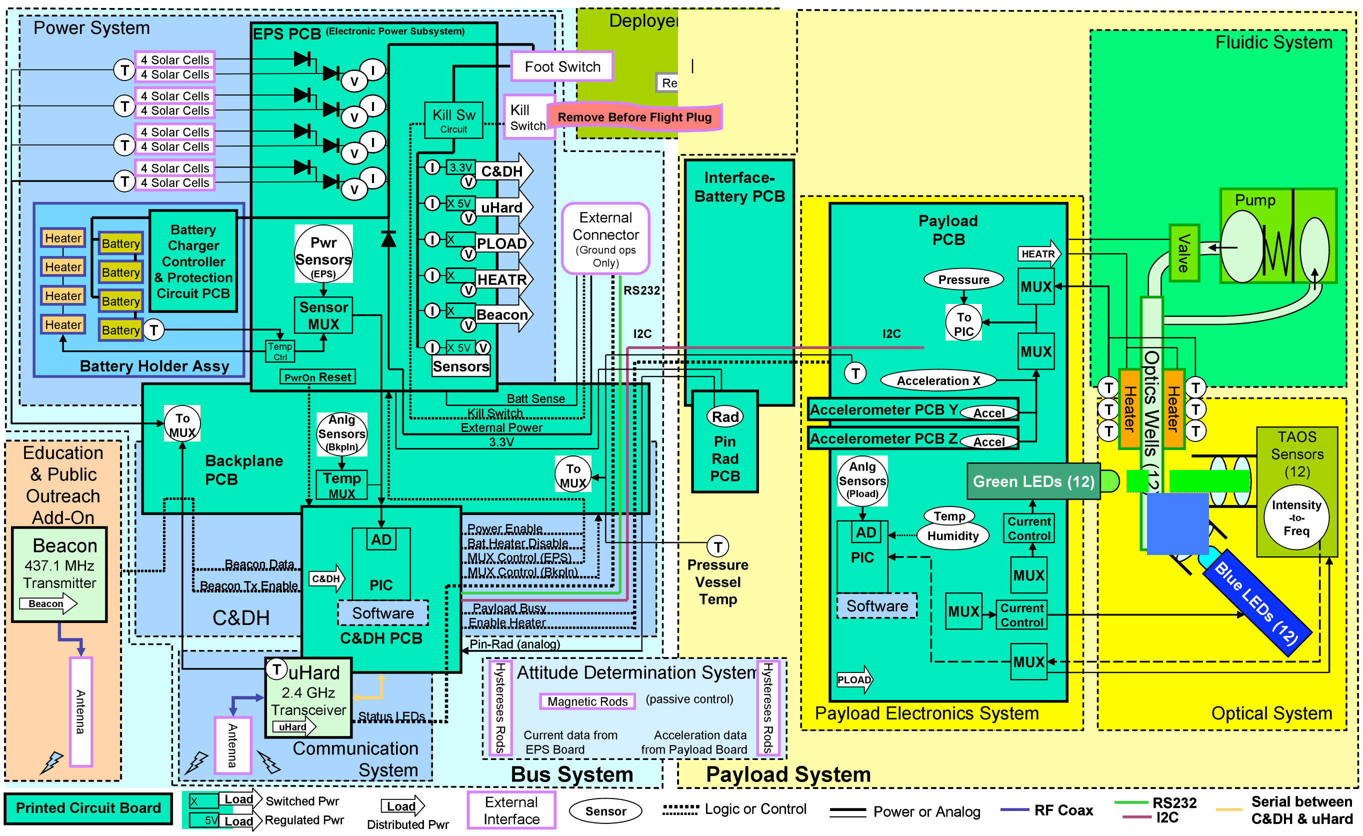


Figure 11, Satellite Electronics Functional Block Diagram

8.4.2 Assembly, PharmaSat Payload System -M100

The PharmaSat payload is comprised of the physical and functional elements illustrated in Figure 17. For more Detail refer to Drawing Tree XM001

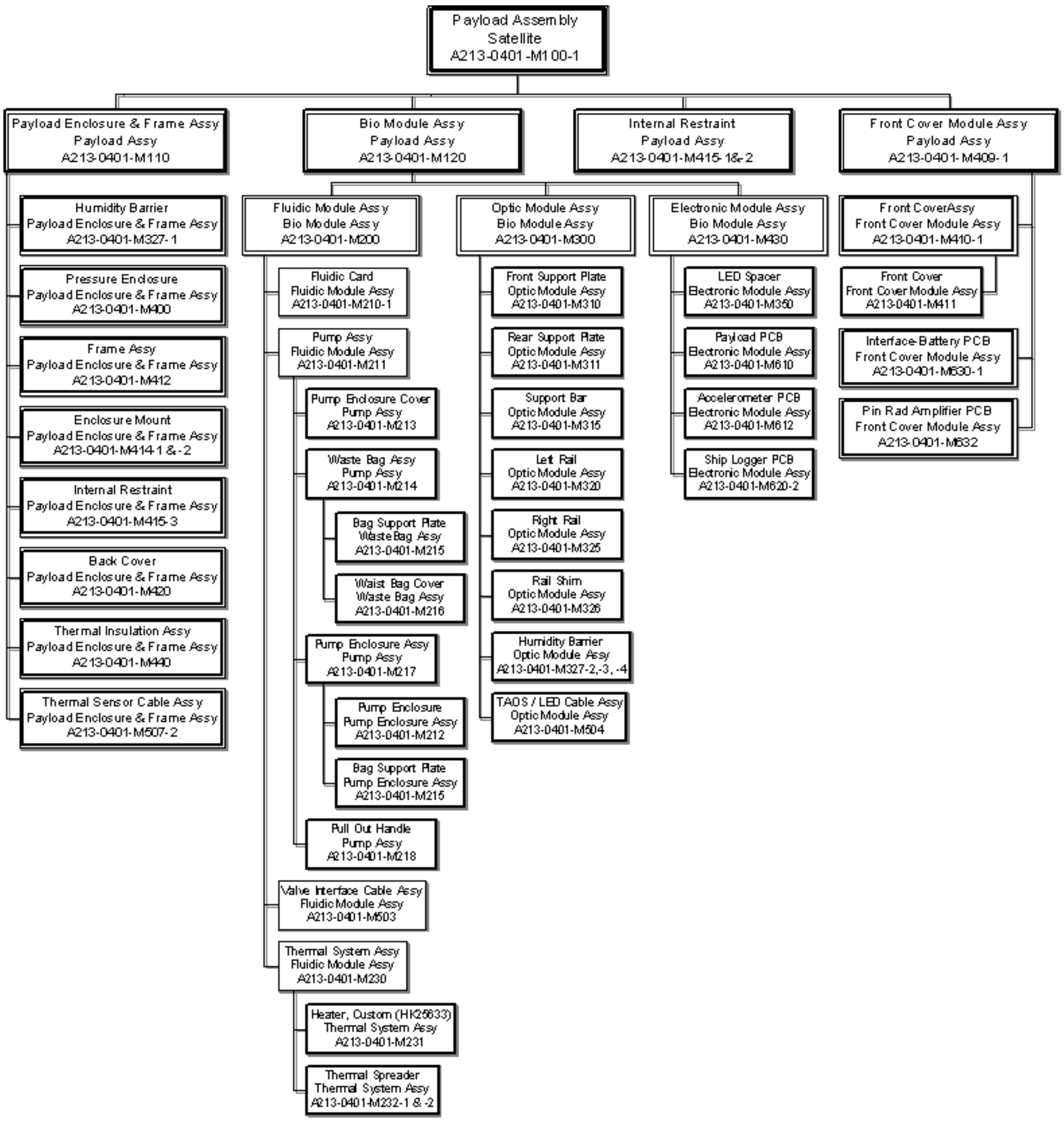
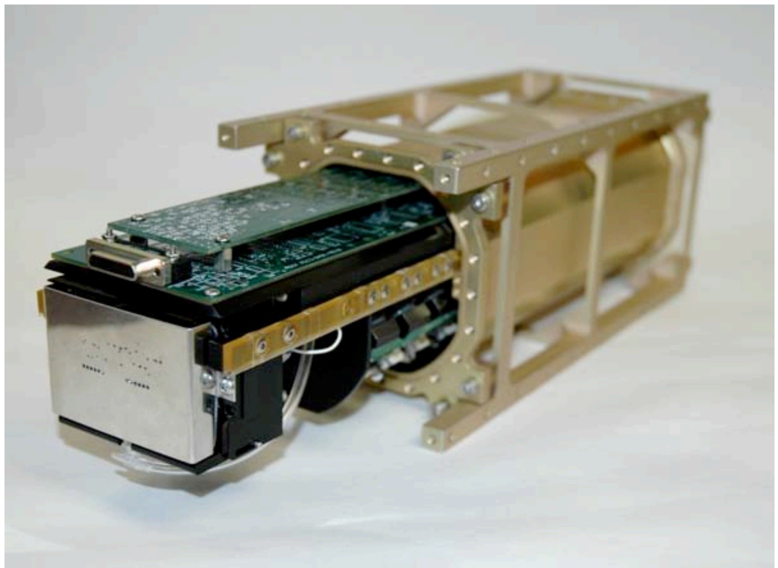
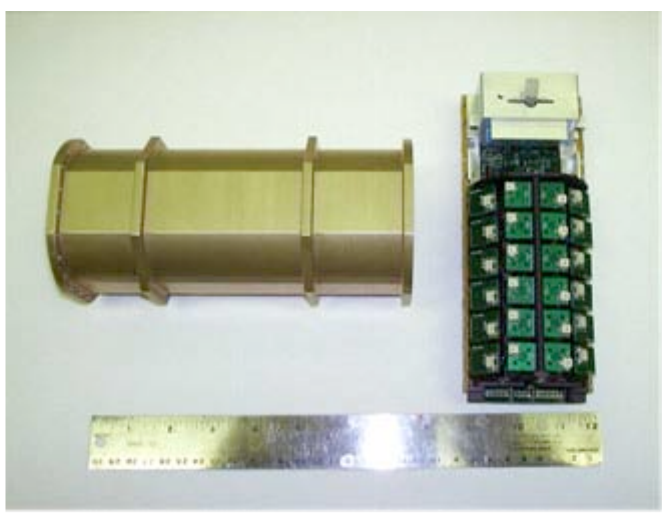


Figure 12, PharmaSat Payload System.

Figure 18 (a, b) shows the PharmaSat payload engineering development unit. The payload system is the primary science payload and all of its integrated subsystems. This system is integrated into the Spacecraft which is subsequently integrated into the Spacecraft Deployment System (on-orbit deployer) and then the Launch Vehicle.



(a), Payload Assembly Partially in Pressure Vessel



(b), EDU Pressure Vessel and Payload Assembly Separated

Figure 13, PharmaSat EDU Payload

Figure 19 shows the a high-level view of the functional organization of the payload electronics. If used, the Ship Logger electronics* serve primarily to capture system health and status information during ground transport, while the main electronics board serves primarily to operate the experiment, control the payload temperature, and transfer data to and from the spacecraft bus.

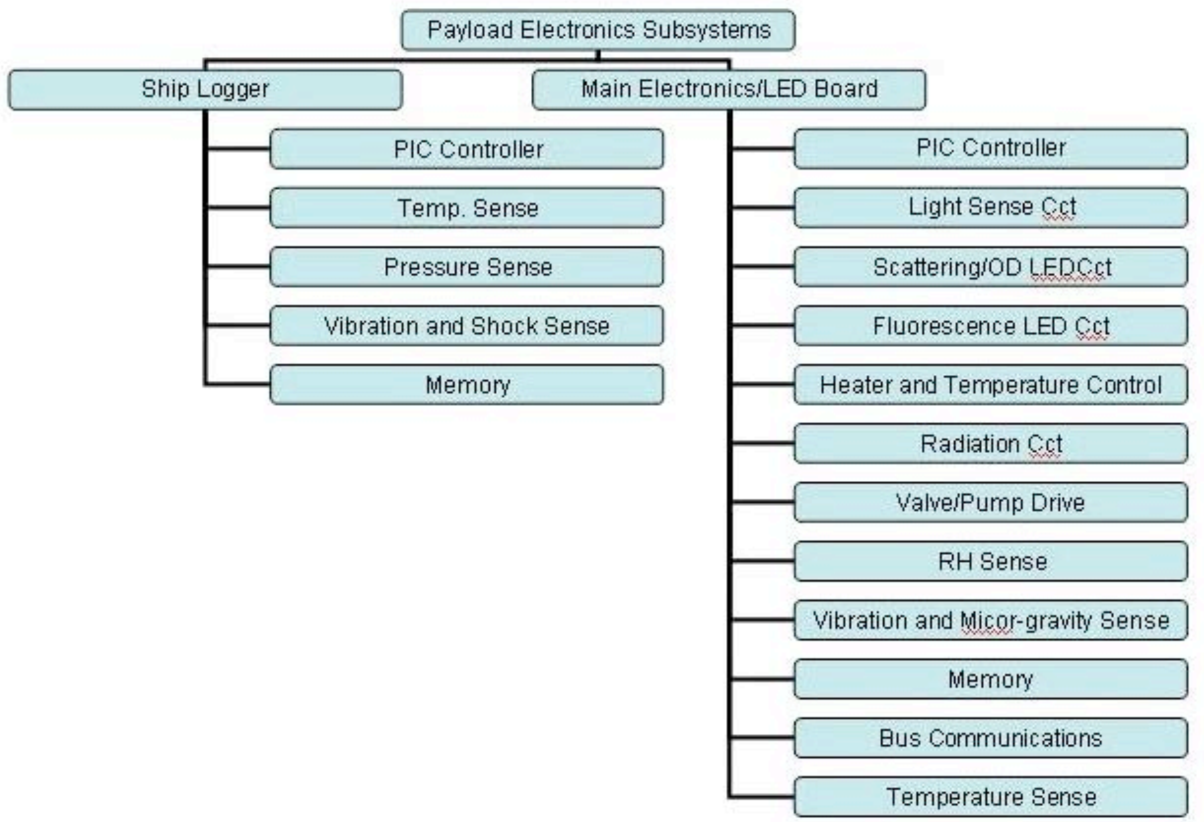


Figure 14, Payload Electronics Functional Organization (showing optional ship logger electronics*, not used in PharmaSat)

* IMPORTANT: PharmaSat does not use ship logger electronics. Instead, ground transport temperature data is provided through 1) an external “Hobo” brand recording device, and 2) Launch Vehicle on-pad temperature monitoring.

8.4.3 Fluidics Wellplate Card

The primary function of the Fluidic Subsystem is to contain biological samples in an array of twelve assay wells and allow fluid delivery to the assay wells through micro-fluidic channels. Ten wells contain biological samples and two wells contain optical calibration material. The fluidic system is illustrated in Figure 20.

Samples of *Yeast* are dispensed into an assay well with a 6.5 mm diameter and 3.0 mm depth. The assay wells are spaced on an 18 mm grid to facilitate ground-based studies using laboratory equipment that can read SBS standard microtiter plates. After *Yeast* introduction, the assay well is sealed with a membrane using a pressure-sensitive adhesive, and the assay wells are filled with stasis media via the micro-fluidic channels. The fluidic card features one inlet micro-fluidic channel and one outlet micro-fluidic channel per assay well. Membranes across the micro-fluidic channels on either side of the assay well allow fluid flow but prevent *Yeast* from escaping through the micro-fluidic channels.

During experiment initiation, nutrient media required for Yeast growth is delivered to each well through the micro-fluidic channels using a pump and valve system which drives fluid from a media bag to the card via tubing and fluidic connectors (the pump system is part of the mechanical subsystem). The stasis media is displaced by the nutrient media and exits the assay well. The fluidic card is supported by the PharmaSat Payload mechanical

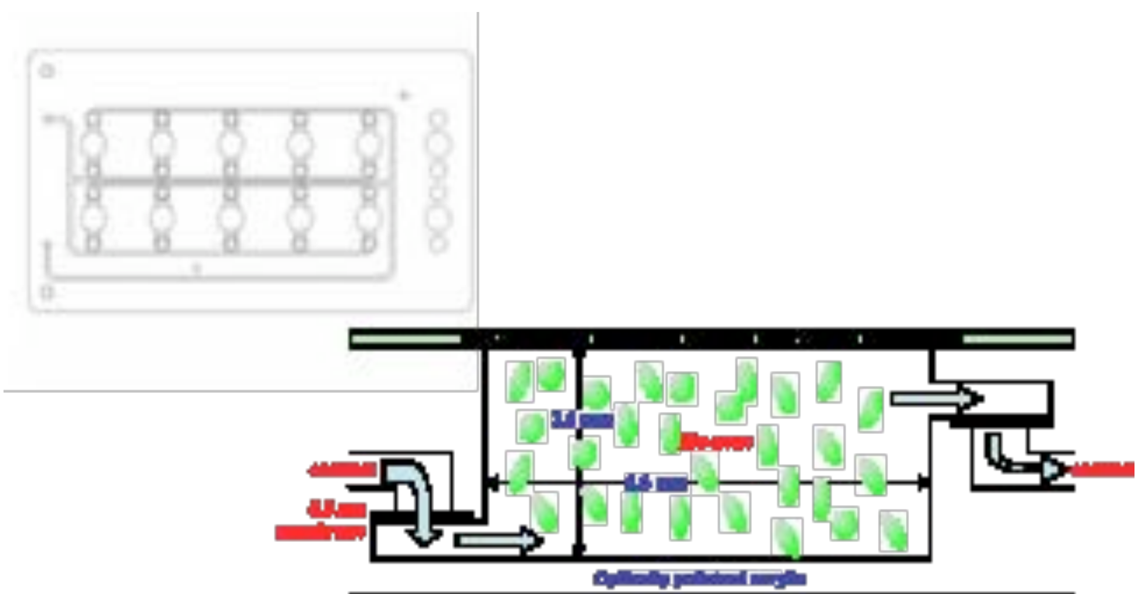


Figure 15, Fluidics Wellplate and Single Well Cross-section

8.4.4 Optics Module

The PharmaSat experimental payload was designed to perform both fluorescence and optical density assays of biological specimens in an automated fashion. Please refer to Figure 21.

The biological sample of interest, in this case Yeast, is placed inside the fluidic card wells. A complete optics unit sits below each well for a fully redundant assay system. The sample is excited with blue light (wavelengths of approximately 460 - 490 nm). The tagged fluorescent proteins of the sample respond by emitting green light (wavelengths of approx. 505 - 530 nm) which is detected by a photodiode. A set of off-the-shelf lenses and color filters ensure that only blue light of the desired wavelengths reaches the sample and only green light of the desired wavelengths reaches the detector.

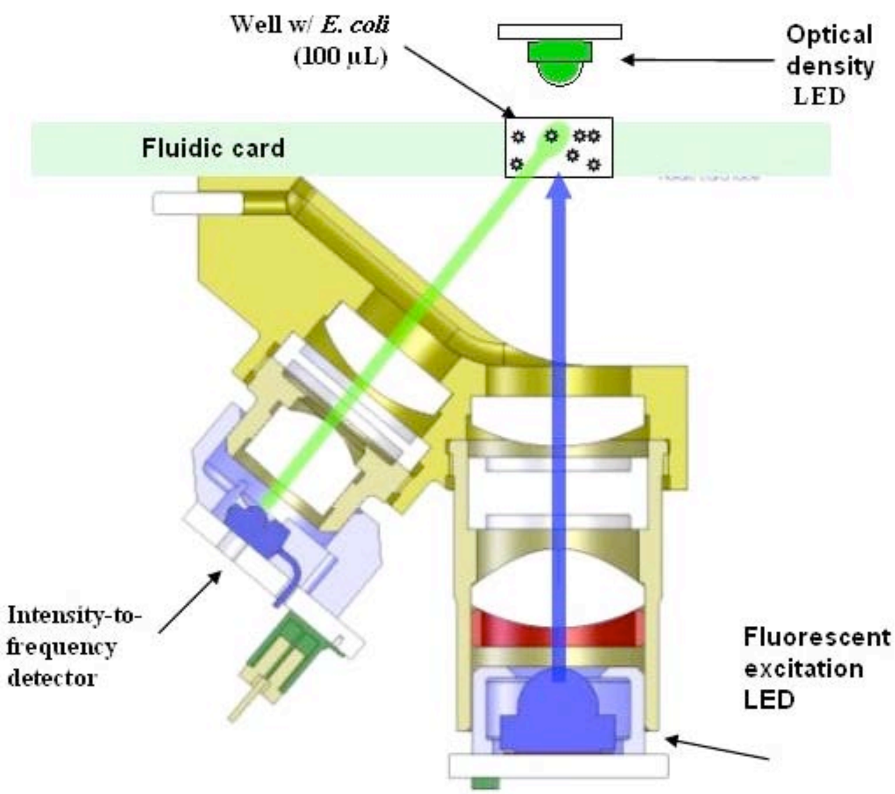
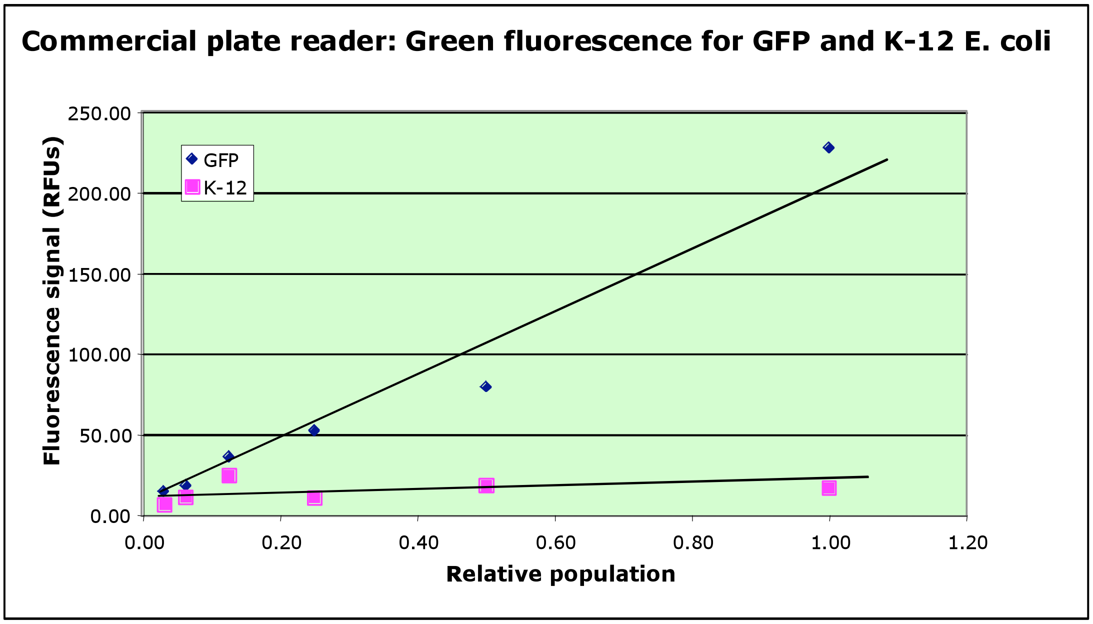


Figure 16, Separately packaged illumination and collection legs allow for minimal background signal on the detector, increasing sensitivity.

An optical density (light scattering) measurement is taken by placing a green LED atop the fluidic card well and again using the collection optics to measure light scattered by the sample.

The goal for both the fluorescence and optical density measurement techniques is to achieve a detection sensitivity comparable to the benchtop equipment. Results for the fluorescence assay are shown in Figure 22.



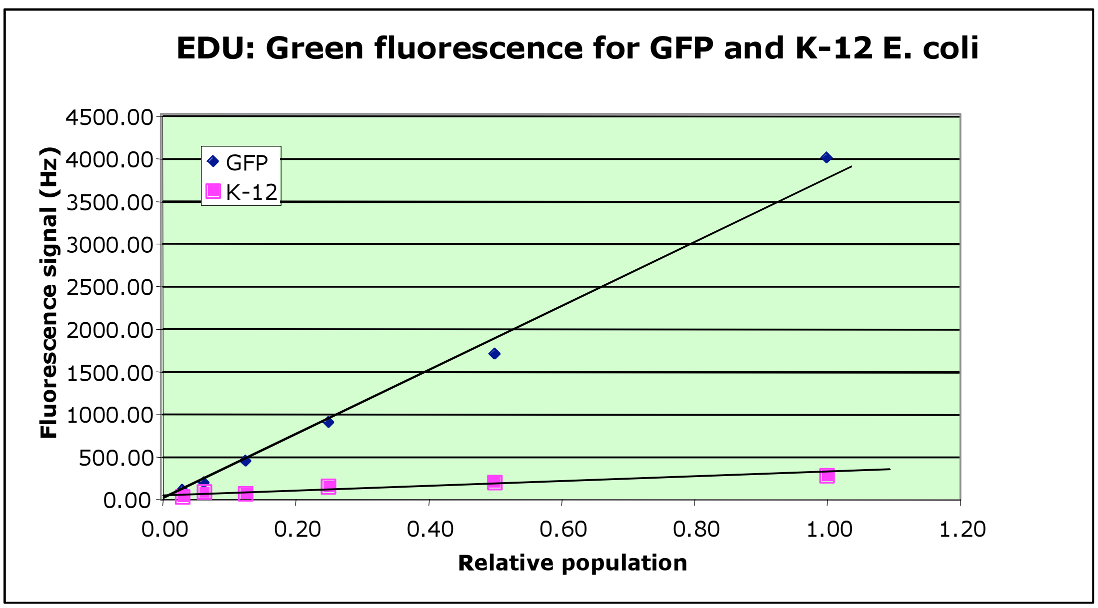


Figure 17, Fluorescence emission of GFP vs. non-GFP Yeast. The top plot shows data recorded by a full-size bench top Molecular Devices Gemini fluorometer. The bottom plot shows the same measurements taken by our EDU (engineering design unit).

8.4.5 Thermal Insulation

The payload thermal insulation system is made up of mutiple elements described as follows and illustrated in Figures 23, 24, and 25:

Frame and Pressure Vessel interface insulators:
The payload pressure vessel is insulated from the main payload external frame structure with mounting brackets made of Ultem™. The internal wellplate assembly is also insulated from the pressure vessel with Ultem™. This is illustrated in Figure 25.

External insulation (See Figures 23 and 24) :
The payload external insulation covering is made of two components. First a layer of Aerogel™ is wrapped over the surface of the payload pressure vessel between the structural reinforcement ribs (Figure 23). Then a 10-layer Multi-layer Insulation (MLI) blanket is wrapped over the top (Figure 24) of the Aerogel™.

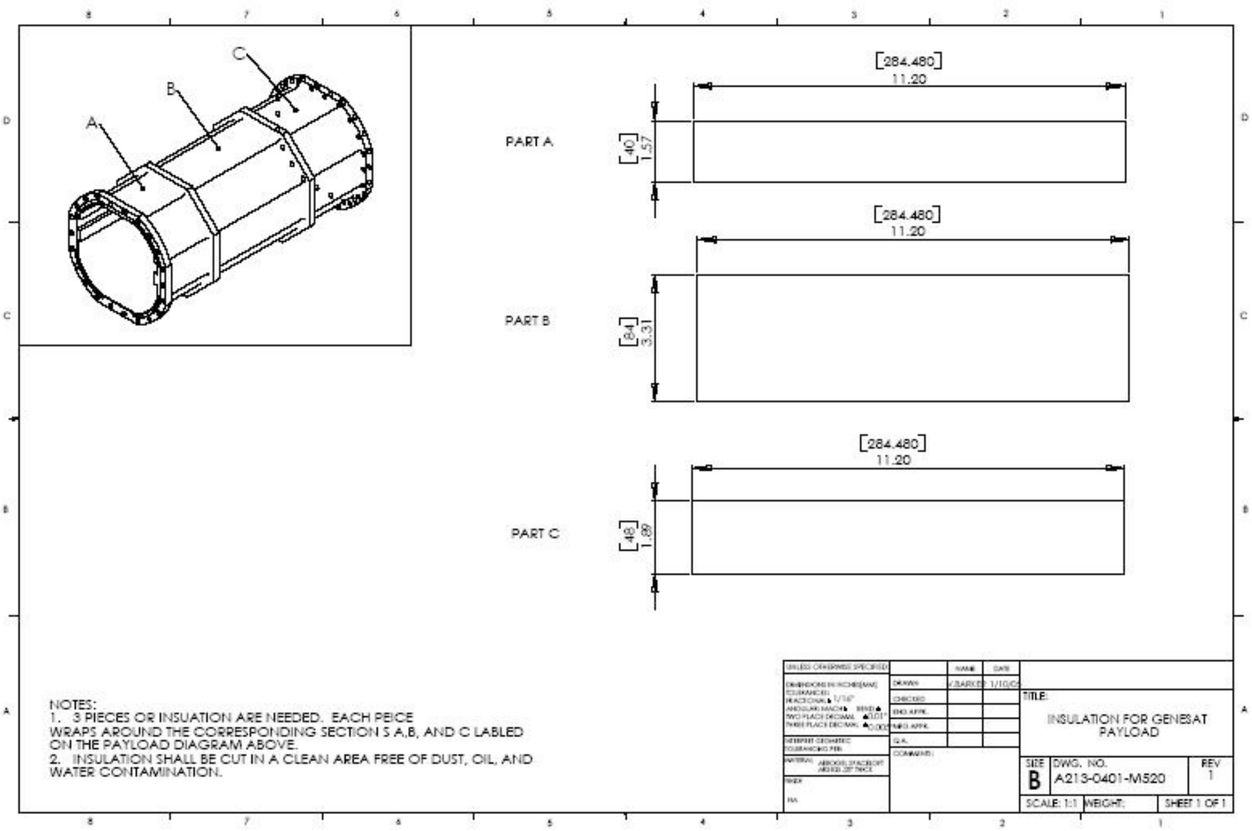


Figure 18, Arogel™ Insulation Assembly

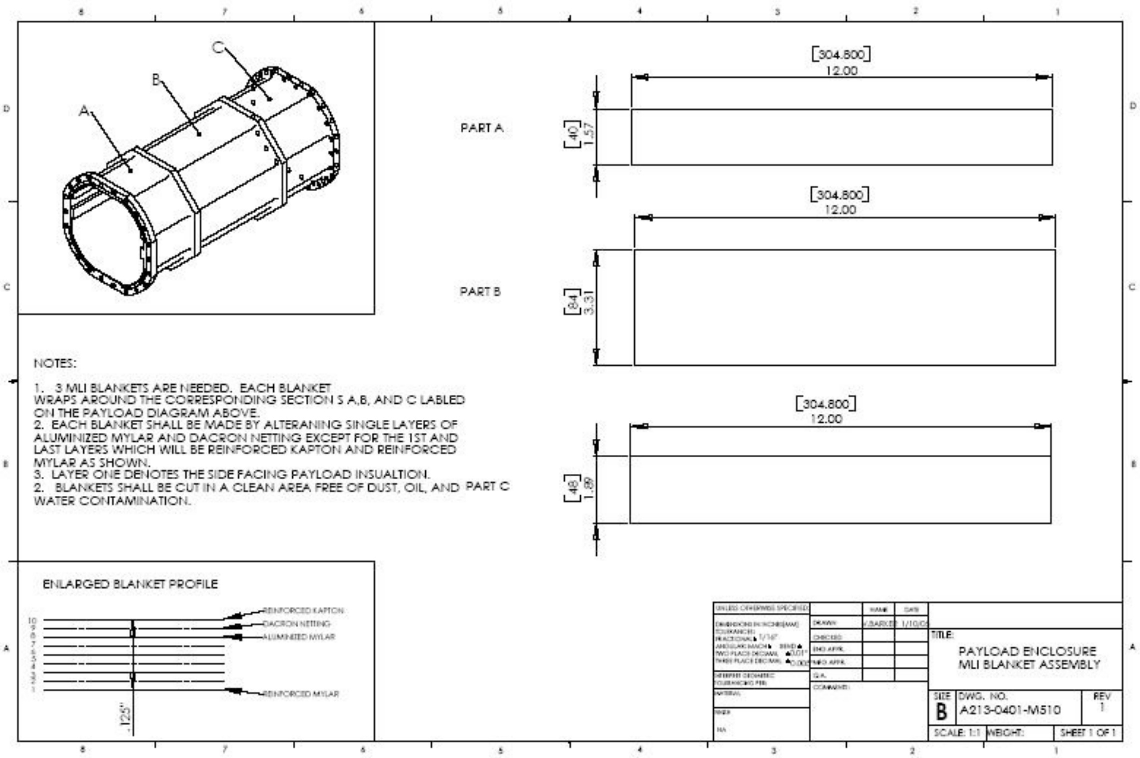


Figure 19, EDU MLI Insulation Design

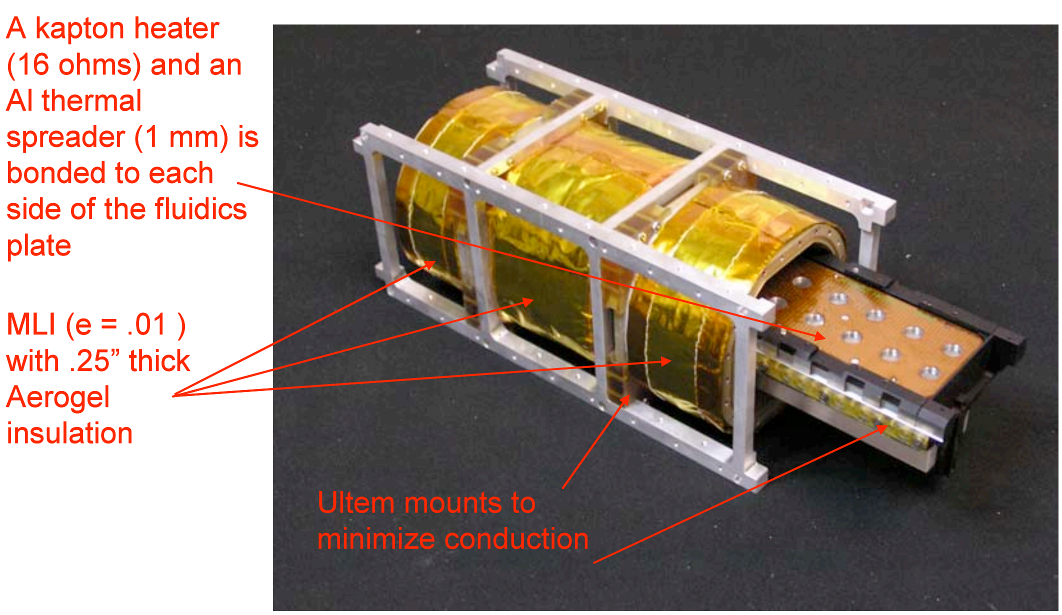


Figure 20, Thermal System Installation Locations on EDU

8.5 Spacecraft Bus

The Spacecraft bus system carries the PharmaSat payload throughout the mission. The bus provides all power and uplink/downlink communications. The bus also manages remediation of Single Event Effects not corrected by the payload. Figure 26 illustrates the functional elements of the spacecraft bus. Figure 27 shows the bus with electronics in place (payload frame extension areas, the locator beacon, antennas, and solar arrays are not shown).

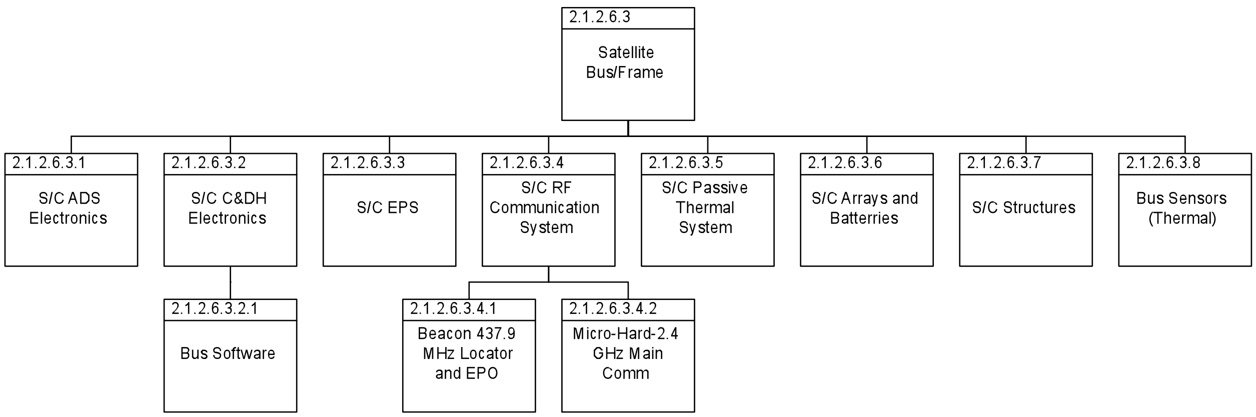


Figure 21, Satellite Bus Systems (Note: beacon frequency may differ.)

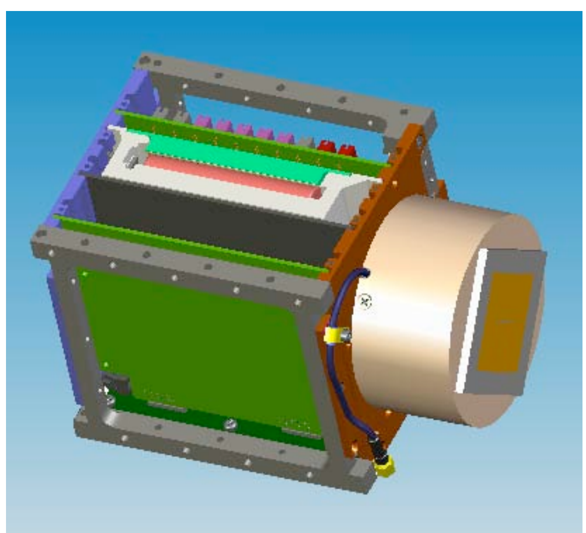


Figure 22, Satellite Bus / Beacon Assy

9 Risk Reduction Test Systems

Risk Reduction Test Systems include existing and newly developed systems used to validate critical subsystem design concepts and demonstrate required performance in relevant environments. Major facilities providing test support are listed below.

Table 2, Facility Locations and POCs

Facility Name / Acronym	Description	Location
ARC-Bio-labs	Laboratories used for development and test of biological experiment procedures and cultures.	Moffett Field, California.
ARC-Test-Lab	NASA Ames Research Center test facility used for payload system-level Qualification, Verification, and Acceptance testing and subsystem-level environmental testing.	N244, Moffett Field, California.
ARC-Fabrication Shops	Metal fabrication and assembly shops.	Various Locations Moffett Field, California.
ARC-Devel-labs	Small laboratories used for developmental bench-testing of subsystem hardware technologies and software.	N213, B19, and others TBS Moffett Field, California.
SCU Labs	Laboratories located at Santa Clara University's Robotic Systems Laboratory are used for ground segment and mission operations development, satellite functional testing, etc.	Bannan Engineering Building, Santa Clara University, Santa Clara California
STC-laboratories.	Space Technology Center laboratories used for developmental bench-testing of spacecraft bus hardware and software.	Bldg. 583c NASA Research Park, Moffett Field California
Stanford Labs	Laboratories located at Leland Stanford Junior University, Palo Alto, California	
Ground Station	Laboratories located at Leland Stanford Junior University, Palo Alto, California	Bldg. 583c NASA Research Park, Moffett Field California
Manufacturer and Subcontractor Facilities	Various manufacturers and subcontractors test facilities. The primary manufacturers are L&M Electronics, Optics 1and , A-LINE Plastics.	TBS
Remote Facilities	Various sites specified when required for specific project needs (e.g. remote antenna tests).	TBS
Lockheed Martin Test Facility	Satellite test facility.	Sunnyvale, Ca.
Minotaur Launch Site	Pre-launch payload preparation facilities, launch operations facilities, and range safety systems.	Wallops Island, VA